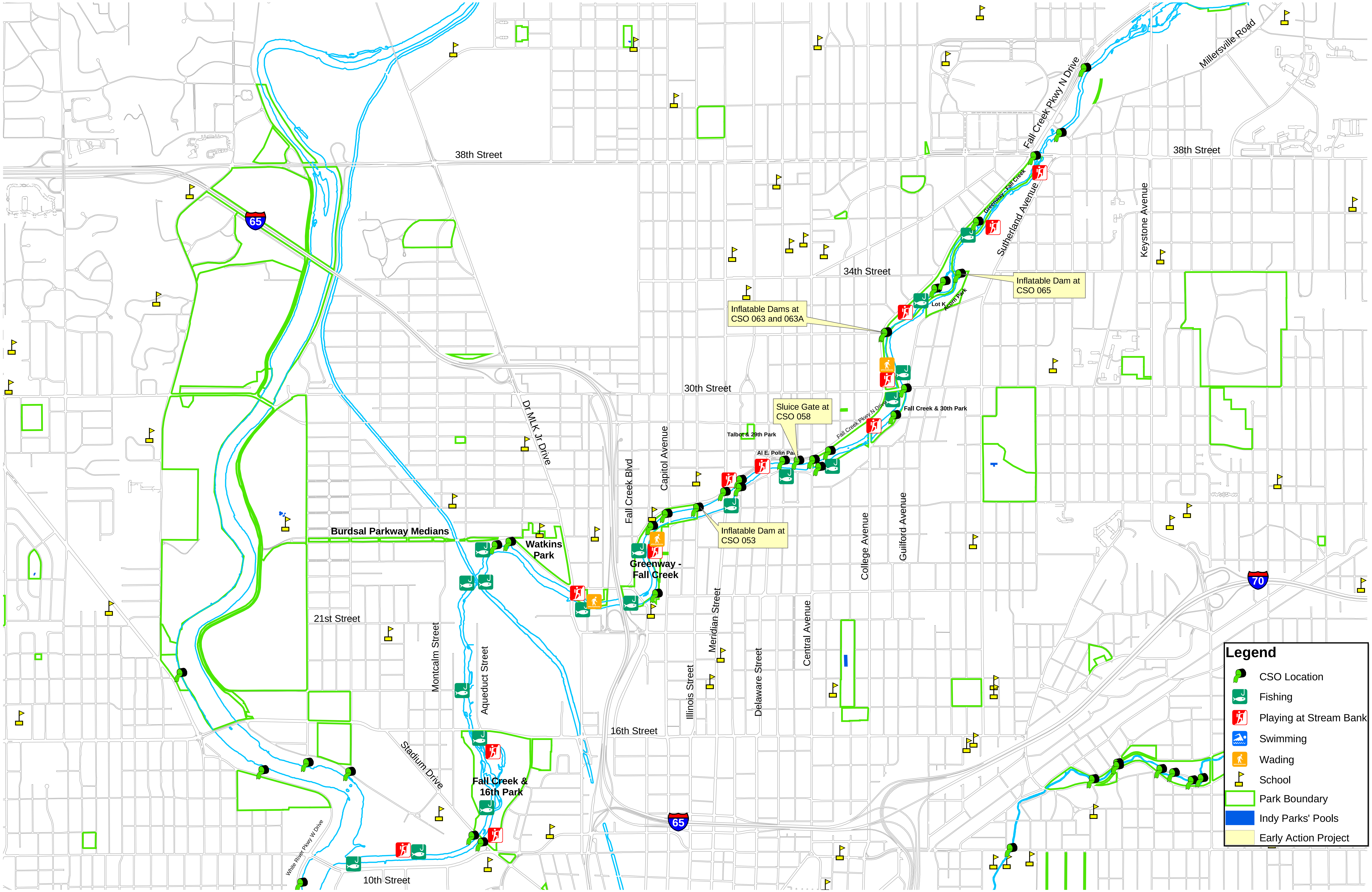
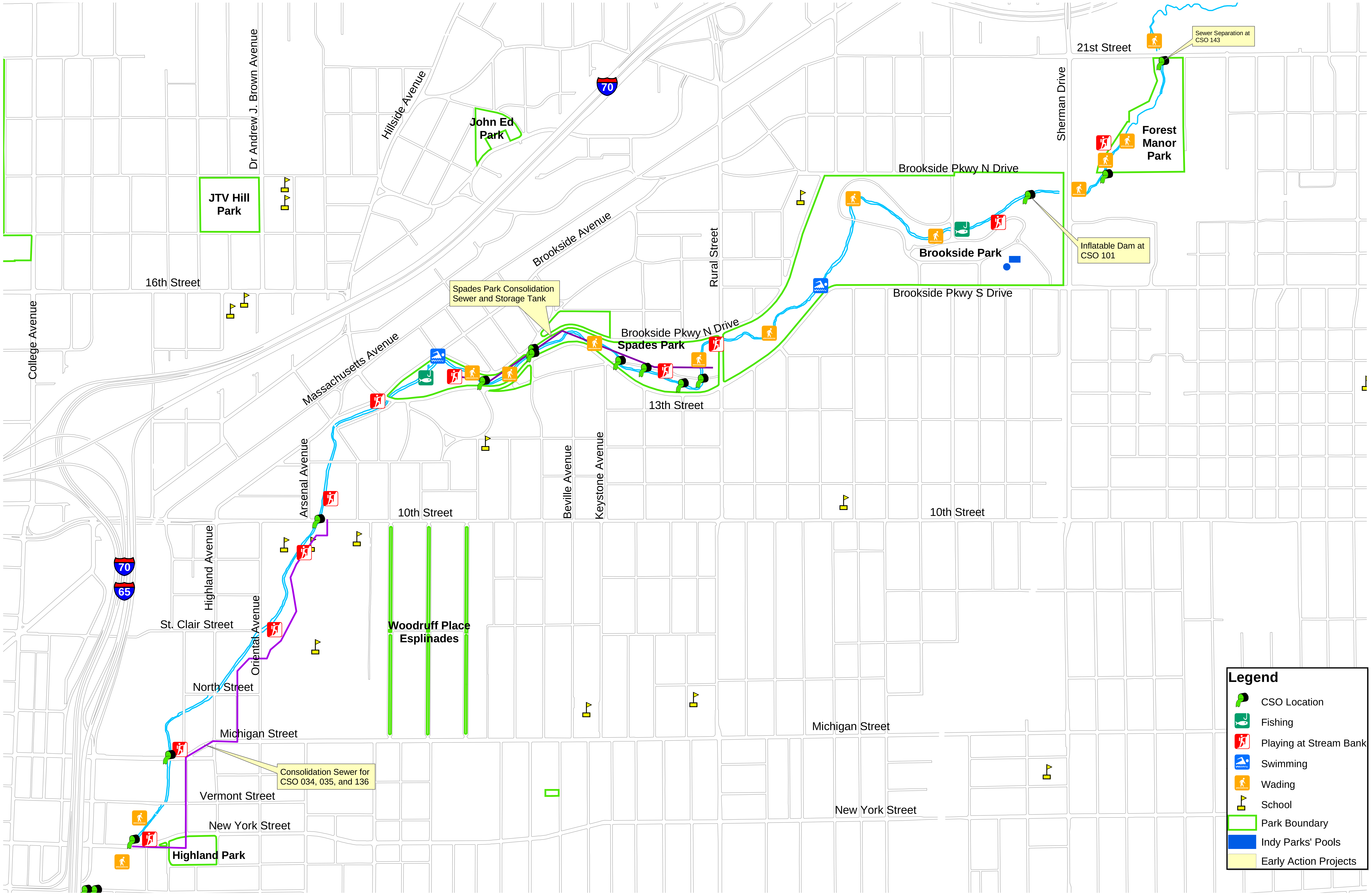



**Note: Located upstream of this map, an early action project at CSO 103 will have sewer separation and rehabilitation.**

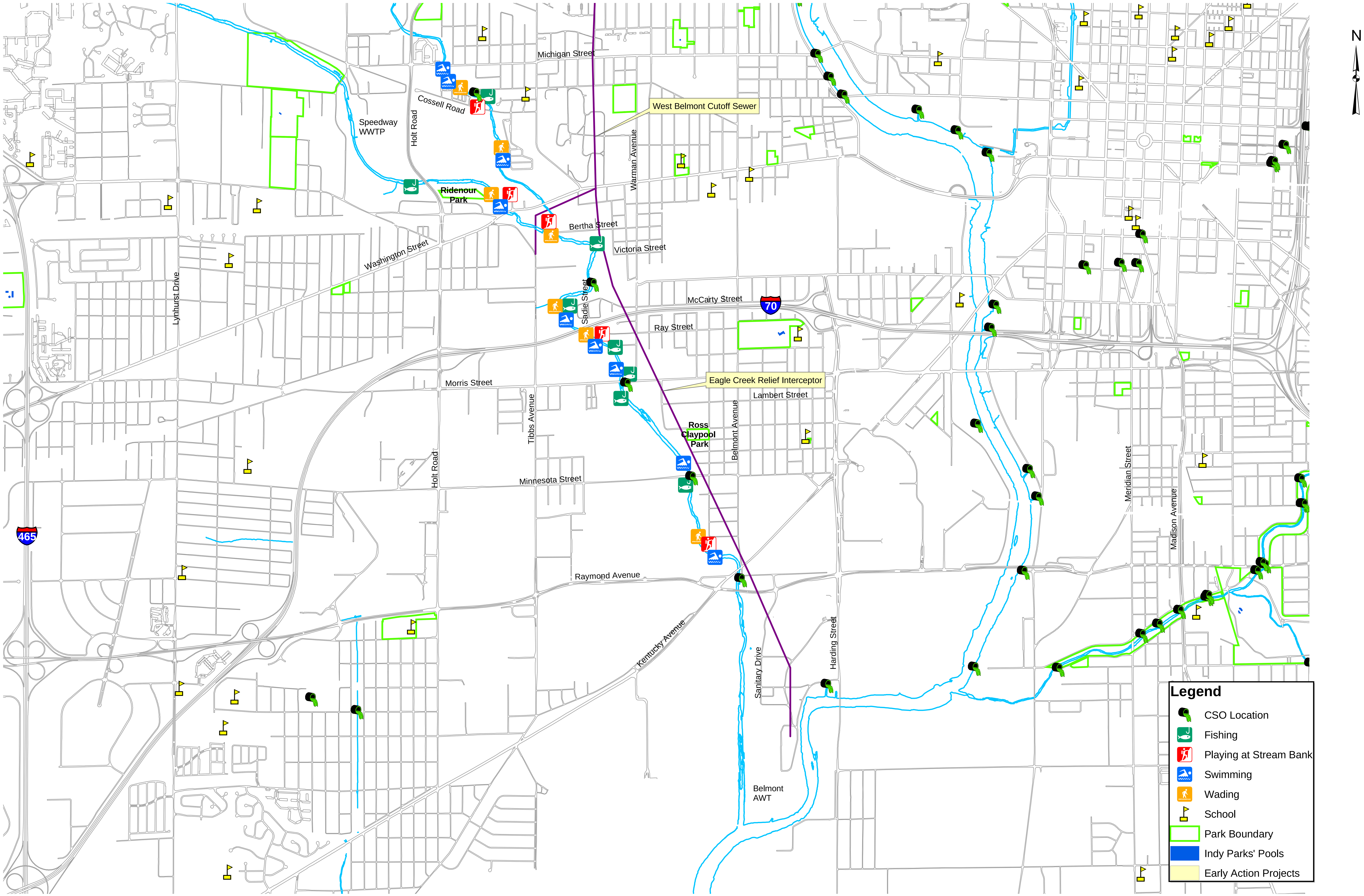
**Appendix A8**
**Fall Creek**
**Reported and Observed Uses**


Appendix A9
Pleasant Run
Reported and Observed Uses




Note: There is also an early action project for Pogues Run on converting part of the tunnel for storage.

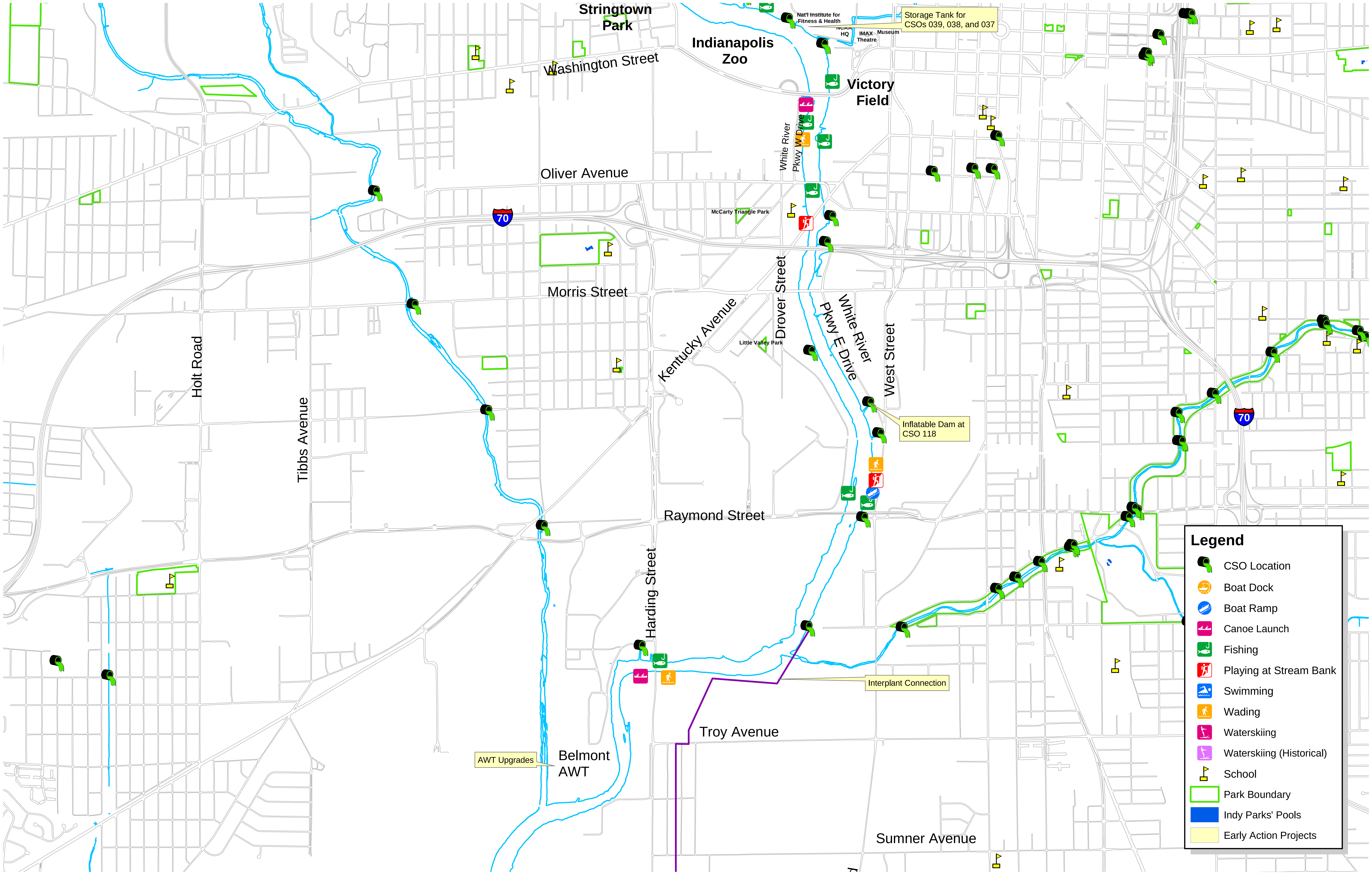
**Appendix A10**
**Pogues Run**
**Reported and Observed Uses**




**Appendix A11**
**Eagle Creek**
**Reported and Observed Uses**

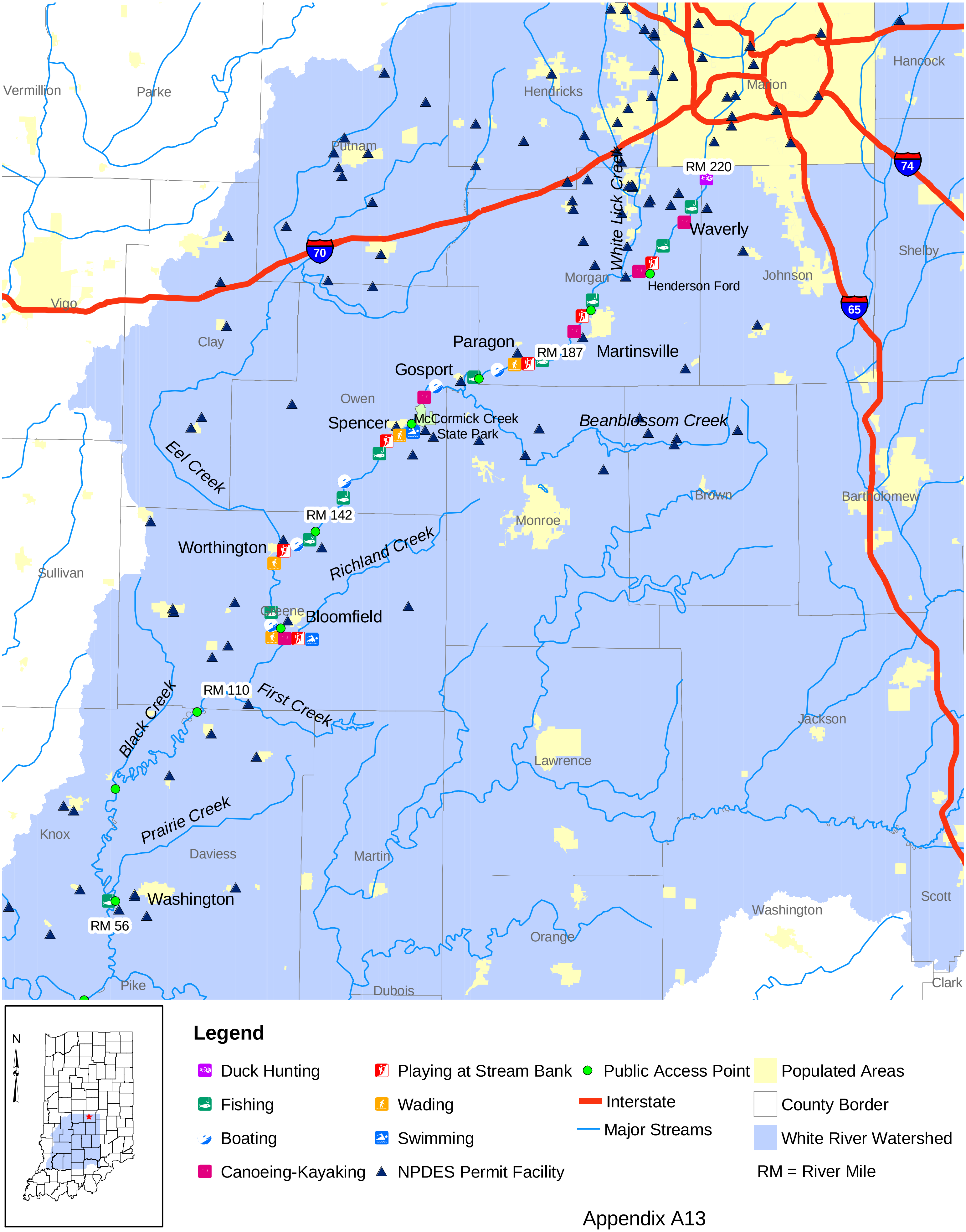

Appendix A12a
White River
Reported and Observed Uses
Sheet 1 of 4


Appendix A12b
White River
Reported and Observed Uses
Sheet 2 of 4




**Appendix A12c**
**White River**
**Reported and Observed Uses**
**Sheet 3 of 4**


**Appendix A12d**
**White River**
**Reported and Observed Uses**
**Sheet 4 of 4**




Appendix A13
White River Downstream of Marion County
Reported and Observed Uses

(IGS, 2004, http://igs.indiana.edu/arcims/statewide/download.html)
(Purdue University CAAGIS, 2004, http://danpatch.ecn.purdue.edu/~caagis/ftp/gisdata/data.html)

*Indianapolis CSO LTCP Hydraulic and Water Quality Modeling Report*

*August 2004*

CDM

# Table of Contents

# List of Figures

# List of Tables

The purpose of this technical report is to document the development, calibration, acceptance, and application of the hydraulic and water quality models. The models have been used to support the development of the City of Indianapolis Combined Sewer Overflow (CSO) Long-Term Control Plan (LTCP). This report reviews the computer models and their uses to support Indianapolis CSO planning needs.

### Hydraulic Modeling

The Indianapolis combined sewer system hydraulic modeling analysis incorporates two models: Storm Water Management Model (SWMM) and NetSTORM. The SWMM model was used for system hydraulic characterization; individual interceptor analysis; single event analysis; six-month continuous simulations for CSO discharge monitoring reports; and LTCP continuous modeling. The NetSTORM model was used to perform long-term continuous simulations, using the Indianapolis precipitation record of 1950-2003, to (1) generate average annual CSO statistics, (2) screen CSO control alternatives, and (3) estimate recommended CSO facility sizes. SWMM continuous simulations were used to confirm the performance of the recommended facility sizes determined based on the NetSTORM model.

The SWMM model was first developed and calibrated from 1992 to 1996, and recalibrated in 2002 using extensive flow monitoring data from the Supplemental Flow Monitoring and Sampling Program. U.S. EPA performed extensive reviews of the 2002 model recalibration effort and approved the model for CSO LTCP development in June 2002.

### Water Quality Modeling

The Indianapolis receiving stream water quality modeling analysis incorporates two models: the Water Quality Analysis Simulation Program (WASP) and *E. coli* bacteria load model. The dynamic WASP model was used to determine single event dissolved oxygen (DO) and *E. coli* bacteria concentrations, and the *E. coli* bacteria load model evaluated the long-term *E. coli* bacteria performance of the White River and its tributary streams. These data are needed to ensure that the City of Indianapolis is in compliance with state and federal water quality standards.

The WASP model was calibrated in 1999 and recalibrated in 2002 to accurately predict DO and *E. coli* bacteria levels in the streams. U.S. EPA reviewed and approved the model for CSO Long-Term Control Plan development. In 2003, the city completed Total Maximum Daily Load (TMDL) reports for the Indiana Department of Environmental Management (IDEM) for the White River, Fall Creek, and Pleasant Run. The city developed and calibrated *E. coli* bacteria load models to support development of the TMDL reports. IDEM and U.S. EPA accepted and approved the TMDLs for these streams.

This report is organized into four sections. Section 1 provides an overview of the hydraulic and water quality models and their uses. Section 2 describes the development and calibration of the hydraulic modeling tools used to support the LTCP alternatives analysis. Section 3 documents the development and calibration of the water quality modeling tools used to support the LTCP alternatives analysis. Section 4 presents the model results for the various phases of the LTCP alternatives analysis.

# 1.0 Overview of System Models

This section introduces the system models and their uses to support Indianapolis planning needs.

The City of Indianapolis initiated its collection system modeling in 1992. The city subsequently developed a suite of modeling tools that have undergone significant refinement and expansion over the last twelve years, primarily to support combined sewer overflow (CSO) long term control planning (LTCP). A brief timeline of the modeling work follows.

- 1992-1993: Interceptor system model was developed.
- 1994-1995: Interceptor system was optimized.
- 1996-1997: Interceptor system model was calibrated and verified.
- 1998: Water quality (WQ) sampling for initial Water Quality Analysis Simulation Program (WASP) model calibration was performed.
- 2001: Draft CSO LTCP was developed; Storm Water Management Model (SWMM) and WASP models were used for facility sizing and expected WQ performance.
- 2001: Supplemental flow monitoring and sampling was performed for model recalibration.
- 2001-2002: Hydraulic model (SWMM) expansion was initiated for the Southport Advanced Wastewater Treatment Plant (SAWTP) and its tributary interceptors.
- 2002: SWMM and WASP models were recalibrated. Updated SWMM parameters were incorporated into NetSTORM. NetSTORM was validated with the recalibrated SWMM model.
- 2003: Control technologies evaluation began; NetSTORM and WASP models were used for CSO facility sizing and expected WQ performance.
- 2003: Total Maximum Daily Load (TMDL) reports for Fall Creek, Pleasant Run, and the White River were completed. The *E. coli* bacteria load model was developed to support the TMDLs.
- 2003-2004: Watershed alternative evaluations were performed for Pleasant Run and Fall Creek. The NetSTORM, WASP, and *E. coli* bacteria load models were used to support the evaluations.
- 2004: Interplant Connection Facilities Plan began. NetSTORM and SWMM were used for facility evaluation.
- 2004: SWMM model expansions for the South Marion County Regional Interceptor (SMCRI) and Belmont North Interceptors were completed.
- 2004: System Wide Plan Analysis for the Revised CSO LTCP begins.

## 1.1 Collection System Models

The hydraulic models were initially developed for the combined sewer interceptor system. The combined sewer interceptor system contains approximately 82 miles of sewers that serve a 35,500 acre combined sewer area. The combined sewer area is located in its entirety in Marion County, which has a 2000 census population of 860,454. It should be noted that not all of Marion County lies in the combined sewer area.

The SWMM model of the combined sewer interceptor system is a key element for understanding and predicting the hydraulic conditions that cause raw sewage overflows. The SWMM model has been applied primarily to develop the CSO Operational Plan and the Long Term Control Plan. The model is currently used to prepare discharge monitoring reports (DMR) for the combined sewer outfalls, as required by the city's National Pollutant Discharge Elimination System (NPDES) permit. The model was first developed and calibrated from 1992 to 1996, then recalibrated in June 2002 using extensive flow monitoring data from the Supplemental Flow Monitoring and Sampling Program. Since 1996, the SWMM model has been regularly updated and expanded to reflect new sewer system data and include some of the separate areas of the collection system. U.S. EPA performed extensive reviews of the 2002 model recalibration effort and approved the model for CSO LTCP development in June 2002. This approval included expectations for continued model expansion and calibration to support detailed planning during implementation of the LTCP projects. **Figure 1-1** presents the extents of the SWMM model. **Appendix A** contains correspondence from U.S. EPA approving the hydraulic and water quality models for LTCP development.

The NetSTORM model of the combined sewer interceptor system was developed for evaluation of the 1950-2003 historical precipitation record. The model was first developed and calibrated from 1992 to 1996, then validated in 2002 using the recalibrated SWMM model. The NetSTORM model was used to generate average annual CSO statistics, screen CSO control alternatives, and estimate CSO facility sizes for confirmation with the SWMM model.

**Figure 1-2** presents an overall schematic showing the integration and connectivity of the collection system and receiving stream water quality modeling tools.

## 1.2 Receiving Stream Models

To understand and evaluate water quality improvements in the Indianapolis rivers and streams, the city initiated development of a Water Quality Analysis Simulation Program (WASP) model of the receiving streams in 1998. The WASP model was calibrated in 1999 and recalibrated in 2002 to predict levels of dissolved oxygen and *E. coli* bacteria in the streams. U.S. EPA reviewed and approved the model for CSO LTCP development.

In 2003, the city completed TMDL reports for the Indiana Department of Environmental Management (IDEM) for the White River, Fall Creek, and Pleasant Run. The city developed and calibrated *E. coli* bacteria load models to support development of these reports. IDEM and U.S. EPA accepted and approved the TMDLs for these streams.

## 1.3 Report Organization

This report is organized into four sections. Section 1.0 provides an overview of the system models and their uses. Section 2.0 describes the development and calibration of the hydraulic modeling tools used to support the LTCP alternative analysis. Section 3.0 documents the development and calibration of the water quality modeling tools used to support the LTCP alternative analysis. Section 4.0 presents the model results for the various phases of the LTCP alternative analysis. Full page tables and figures are located after Section 4.

## 1.4 Source Documents

This report has been developed from information reported in prior technical documents, which are summarized in **Table 1-1**. Information presented in this report from prior technical documents should not be considered exhaustive. The source documents may be referenced for additional information on the city's model development.

**Table 1-1**
**Summary Of Source Documents**

| Year | Author | Title | Model Reference |
|---|---|---|---|
| 1997 | CSO Project Team | CSO Model Calibration Technical Memorandum | SWMM & NetSTORM |
| 2003 | CDM | Presentation Supplement for CSO Control Technology Evaluation | SWMM, NetSTORM, WASP |
| 2003 | CDM | Fall Creek TMDL Report | *E. coli* bacteria load |
| 2003 | CDM | Pleasant Run TMDL Report | *E. coli* bacteria load |
| 2003 | CDM | White River TMDL Report | *E. coli* bacteria load |
| 2003 | ICST | Stream Reach Characterization and Evaluation Report | WASP |
| 2003 | ICST | Hydraulic Model Calibration and Verification Plan | SWMM |
| 2004 | CDM | South Marion County Regional Interceptor Model Expansion Report | SWMM |
| 2004 | CDM | Belmont North Interceptor Model Expansion Report | SWMM |

# 2.0 Combined Sewer System Hydraulic Model

This section describes the development, calibration, acceptance, and use of the combined sewer system hydraulic modeling tools. The Stormwater Management Model (SWMM) and NetSTORM models are described in detail. Section 4.0 presents the results of the NetSTORM modeling analysis supporting the Combined Sewer Overflow (CSO) Long-Term Control Plan (LTCP).

## 2.1 Approach

The Indianapolis combined sewer system hydraulic modeling analysis incorporates two models: SWMM and NetSTORM. The SWMM model is used for system hydraulic characterization, individual interceptor analysis, single event analysis, six-month continuous simulations for CSO discharge monitoring reports (DMR) and LTCP continuous simulations. The NetSTORM model is used for long-term continuous simulations, using the Indianapolis precipitation record of 1950-2003 to generate average annual CSO statistics, screen CSO control alternatives, and estimate CSO facility sizes. SWMM continuous simulations are used to confirm the performance of the facility sizes based on the NetSTORM model.

Recognizing that the interceptor sewers and regulators, not the combined sewers, control wet weather system conveyance capacity to the wastewater treatment plants (and therefore control the occurrences of CSOs), the City of Indianapolis developed a detailed model of interceptor sewers and regulators using the EXTRAN block of SWMM. For the purposes of this report, combined sewers are defined as the sewers in the combined sewer area upstream of the CSO regulator structures and interceptor sewer. **Figure 2-1** presents a map of the Indianapolis interceptors. The RUNOFF block of SWMM was used to generate runoff flows from drainage subcatchments and to calibrate wet weather flow to the EXTRAN model. The linked SWMM model was used to establish input data for the NetSTORM model of the combined sewer system (CSS), specifically the regulator and interceptor capacities and the rainfall-runoff coefficients. The city performed long-term continuous simulations using NetSTORM to compute average annual CSO frequencies and volumes. The selected modeling strategy enables the city to accurately determine interceptor sewer conveyance and system storage capacities, identify system optimization projects, characterize overflows and pollutant loads to receiving streams, and evaluate a large number of CSO control alternatives.

## 2.2 SWMM

### 2.2.1 Introduction

The SWMM model was developed to provide hydraulic representation of the interceptors and regulator structures in the combined sewer area for CSO operational plan development and CSO long-term control planning efforts. Although several models are available for interceptor modeling, the most widely used and accepted model for this application is the EXTRAN block of the U.S. EPA's SWMM (Roesner et al., 1988). The EXTRAN block solves the full dynamic St. Venant equations for gradually varied, unsteady flow using an explicit numerical solution technique.

Model calibration involves collecting field monitoring data (rainfall and runoff) and developing an initial model input data set. This is followed by successive applications of the model during which calibration parameters are adjusted until the model results match observed data as closely as possible. Calibration is a critical step in ensuring that the model properly simulates flow in the collection system over a range of storm events. Model calibration adjustments must be within an acceptable range for the specified hydraulic parameter. The standard for model calibration is established as +/- 20 percent of the reliable monitored flow depth, flow rate, and volume for CSO LTCP development.

Model development and calibration protocols may vary based on modeling objectives and goals established for each project and level of model detail. For example, in a typical large CSO planning project, hydraulic models are initially developed for the interceptor system and later expanded to upstream sewers to support detailed facilities planning efforts. The level of model development and calibration for facilities planning and design is significantly higher than for long-term planning efforts, in order to achieve the high degree of accuracy in model predictions necessary to support these functions. The SWMM linked model results include correlation of the simulated hydraulic grade line (HGL) and flow rate with the measured values, at various flow meter sites, during selected calibration storm events. The 1997 model calibration is summarized in the CSO Model Calibration Technical Memorandum (CSO Project Team, 1997).

### 2.2.2 2002 Recalibration and Verification

The model recalibration process was initiated in 2001 in order for the SWMM model to be approved by U.S. EPA for use in the LTCP. The goal of the model recalibration process was to demonstrate that the SWMM model is appropriate for simulating system flows and CSO discharges. The model recalibration used flow monitoring data from 17 CSO locations, five combined sewer interceptor locations, and permanent flow monitors upstream of the combined sewer area. This calibration included additional data collected during the supplemental flow monitoring program. **Figure 2-2** presents the locations of these flow monitors. Basin-specific radar-rainfall precipitation data was collected for three calibration rainfall events: August 31, 2001; September 7, 2001; and September 23, 2001.

The specific recalibration goals are as follows: (1) modeled depth at interceptor and CSO regulator locations should be within 20% of the reliable measured data, and (2) modeled CSO activation and event duration should be consistent with reliable outfall data. Activation and duration data are considered to be more accurate than other sources of information available from CSO outfall monitors. The Hydraulic Model Calibration and Verification Plan (ICST, 2003) documents the methodology necessary to ensure that reliable flow monitoring data is collected.

U.S. EPA performed extensive reviews of the 2002 model recalibration effort and approved the model for CSO LTCP development in June 2002. Approval of the model included expectations for continued model expansion and calibration to support detailed facilities planning and design during implementation of the LTCP projects. **Appendix A** contains correspondence from U.S. EPA approving the hydraulic and water quality models for supporting the LTCP revisions.

**Appendix B** contains the final 2002 model recalibration information that U.S. EPA reviewed. The summary figures of the recalibration effort are presented in **Figures 2-3** and **2-4**. Figure 2-3 presents the preliminary and final recalibration scatter plots comparing modeled and monitored HGL in the interceptor and CSO regulator locations. The majority of the data points fall within the 20% accuracy bands, which meets the calibration objective. **Figure 2-4** presents the preliminary and final recalibration scatter plots comparing modeled and monitored volume and HGL in the CSO interceptor locations. The majority of the HGL data points fall within the 20% accuracy bands, which meets the calibration objective. The data points for modeled and metered volume are considered to be accurate, within the limitations of flow metering technology to provide reliable velocity measurements in large diameter sewers. **Appendix C** contains flow monitoring scattergraphs.

### 2.2.3 Model Development from 1997-2004

The Indianapolis SWMM model has been refined as needed to incorporate new information gathered from field investigations and updated records. Examples of the new information include revisions to sewer profiles, subbasin delineations, regulator structure weir elevations, diversion structure operation, Advanced Wastewater Treatment (AWT) operations, and the representation of newly constructed collection system elements. This information has been incorporated into the SWMM model to support the 2001 CSO LTCP, the DMRs from 1999 through 2004, and the 2004 Interplant Connection Facilities Plan. Completion of the DMRs requires that all CSS improvements made in the six-month DMR period receive functional representation in the SWMM model. In 2001 and 2002, the SWMM model was expanded to include the headworks of the Southport AWT Plant (SAWTP) and a portion of its tributary interceptors. The objective was to expand the calibrated interceptor model to the SAWTP and include basic representation of the interceptor sewer network immediately upstream of the plant. Developing a working interceptor model that links the Belmont and Southport AWT Plants enabled the city to perform an overall planning level assessment of the flow diversion between the two plants.

In 2002 and 2003, the SWMM model was expanded to include two key separate sanitary interceptors: the South Marion County Regional Interceptor (SMCRI) and Belmont North (BN) sanitary interceptor. The expanded model will support assessment of the current and future capacity of these interceptors and support implementation of the city's CSO LTCP. The expanded SMCRI model is more detailed than the basic representation developed in the 2001-2002 Southport expansion, and is intended to be used for performing overall planning level hydraulic assessments under existing and future conditions. The development and calibration of the model expansions is documented in the South Marion County Regional Interceptor Model Expansion Report (CDM, 2004) and the Belmont North Interceptor Model Expansion Report (CDM, 2004).

## 2.3 NetSTORM

### 2.3.1 Introduction

The Storage Treatment Overflow Runoff Model (STORM) is a hydrologic model developed in the early 1970s and widely used to characterize urban stormwater runoff. STORM is a planning-level model that is applied for quantity and quality analyses of urban watersheds and for screening storage/treatment alternatives. Since its early implementation on mainframe computers, STORM has gained recognition as a practical and effective computer model for planning-level simulation of urban watersheds, especially those with combined sewer systems. STORM has since migrated to the microcomputer environment, where it remains a popular and widely used hydrologic model.

Typically, the CSS representation in STORM consists of detailing areas tributary to each modeled overflow structure. Routing of treated flows to a downstream structure for further treatment or splitting flows between two CSO drainage areas is not included in the core STORM formulation and coding. However, many prototype systems route treated flows through a network of structures, and need additional modeling capability to accurately represent the system and estimate CSO statistics. CDM developed an improved version of STORM (NetSTORM) that incorporates algorithms to simulate flow routing through networked structures. Because the Indianapolis sewer system contains numerous flow diversion structures that divert flow to different drainage basins, the NetSTORM version of STORM was applied to allow for representation of these flow diversion structures.

### 2.3.2 Development

NetSTORM performs continuous simulations to characterize CSOs using the Rational Method (modified to account for depression storage explicitly) to compute runoff, incorporate dry weather flow, and route combined sewer flows through conveyance, storage and treatment at each time step. The NetSTORM model was applied to the Indianapolis CSS to develop CSO frequency and volume statistics. Overflow statistics (frequencies and volumes) were developed for each structure that discharges to receiving water, or to a downstream structure.

The NetSTORM model was initially calibrated using rainfall and field monitoring data from selected calibration storm events by adjusting the calibration parameters to match combined sewer flow volume and CSO frequency with the field monitoring data. The SWMM model was used to establish critical input data for the NetSTORM model of the CSS, specifically the regulator and interceptor capacities (NetSTORM treatment rates) and the rainfall-runoff coefficients (NetSTORM C-values).

Three storm events were used for calibration of the NetSTORM model, and three separate storm events were used for verification. The original calibration efforts are summarized in the CSO Model Calibration Memorandum (CSO Project Team, 1997).

### 2.3.3 Validation

After the SWMM model recalibration was completed in 2002, the recalibrated SWMM model was used to provide validation for the NetSTORM model. Ten historical rain events were selected from the 1950-2003 Indianapolis rainfall database. The events were chosen to create a range of small, short storms, and large, long storms. The rain events were also screened for hyetograph shape, time to peak, and stability of modeling in SWMM. **Table 2-1** contains a summary of the rain events.

In addition to the 10 historical rain events, the 1-month, 1.7-month, 3-month, 6-month, and 24-month SCS Type II design storms were also simulated in NetSTORM and SWMM. **Figure 2-5** displays a comparison of the modeled systemwide CSO volume for the rain events.

The impact of the SWMM recalibration effort on the NetSTORM model performance is documented in the Presentation Supplement for CSO Control Technology Evaluation (CDM, 2003). The NetSTORM model accurately reflects the SWMM model, within its assumptions and limitations, and was used to evaluate of a large number of CSO control alternatives for the CSO LTCP. The results of the NetSTORM modeling analysis can be found in Section 4 of this report.

# 3.0 Water Quality Models

This section describes the development, calibration, acceptance, and use of the receiving stream water quality modeling tools. The Water Quality Analysis Simulation Program (WASP) and *E. coli* bacteria load models are described in detail. Section 4.0 presents the results of the water quality modeling analysis supporting the Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP).

## 3.1 Approach

Two modeling tools were used evaluate the water quality performance of the White River and its tributary watersheds. The dynamic WASP model was used to determine single event dissolved oxygen (DO) and *E. coli* bacteria concentrations. WASP model results for single event simulations were compared against the minimum DO standard of 4.0 mg/L, the minimum 24-hour average DO standard of 5.0 mg/L, and the *E. coli* bacteria daily maximum standard of 235 cfu/100 mL.

To evaluate the long-term *E. coli* bacteria performance of the White River and its tributary watersheds, an *E. coli* bacteria load model was developed as part of the Total Maximum Daily Load (TMDL) preparation. The model simulates *E. coli* bacteria discharged from various sources including CSOs and urban and residential nonpoint sources during dry and wet weather.

While the WASP model was used to predict the *E. coli* bacteria concentration for a single event, the *E. coli* bacteria load model predicts daily *E. coli* bacteria concentrations for the historical period of 1991-2001. The ten-year simulation period is necessary in order to evaluate water quality performance against (1) the *E. coli* bacteria monthly geometric mean standard of 125 cfu/100 mL, (2) the reference criteria of no more than 10% of samples above 235 cfu/100 mL, (3) the reference criteria of no samples over 10,000 cfu/100 mL, and (4) two additional bacteria levels of 2000 cfu/100 mL and 5000 cfu/100 mL. The reference criteria are documented in the Indiana Department of Environmental Management's (IDEM) 303(d) Listing Methodology (IDEM, 2002).

## 3.2 WASP

This section describes the development, calibration, acceptance, and use of the WASP model. Additional information on the WASP model is documented in the Stream Reach Characterization and Evaluation Report (ICST, 2003).

### 3.2.1 Introduction

**Figure 1-1** presents the White River receiving water modeling strategy used in this study. As shown in the figure, the modeling strategy begins with the evaluation of hydrology and hydraulics using the U.S. EPA Storm Water Management Model (SWMM). The total study area was divided into the combined sewer areas and separate sanitary sewer areas. Combined sewer overflow rates calculated in the SWMM model were used to represent the combined sewer flow contribution to the stream system, while the RUNOFF block of the SWMM model was used to calculate the rates of stormwater runoff entering the stream system from separate sanitary sewer areas. The rate of runoff at any given location is dependent upon precipitation, land area, impervious cover, land slope and other physical parameters.

The stream hydraulics were modeled using the EXTRAN block of the SWMM model. Dry weather conditions were modeled to establish the base conditions of flow rate, velocity and depth before the onset of a storm event. Wet weather events were modeled to evaluate the routing of baseflow, stormwater runoff and CSO flows through the stream system.

Once the hydrology and hydraulics models were established, the water quality evaluation was initiated. Many of the important parameters required for instream water quality modeling were developed using the results of the hydrology and hydraulics models. These physical parameters are important in determining the rate of key instream water quality processes, which are discussed further in Section 3.2.3.

### 3.2.2 Development

The SWMM hydraulic model, which is described in Section 2.2.1, calculates combined sewer overflow rates at various locations in the sewer system. The overflow rates are then mapped to the appropriate receiving water quality model stream segment. For separate sanitary sewer areas, the total area of 2,421 square miles was subdivided into model subbasins, based on delineations using United States Geological Survey (USGS) quadrangle maps. As with combined sewer flows, separate sanitary sewer flows were mapped to the appropriate stream network segment.

In 1998, an EXTRAN model of the stream network was developed using available stream cross-section data, supplemented by data collected in the field. The model consisted of the White River and Fall Creek stream segments. The WASP water quality model of the stream network is directly comparable to the EXTRAN hydraulic receiving water model. The three key input categories for water quality modeling in WASP include physical stream parameters, water quality constituent loads, and instream rate constants. The key modeled constituents for modeling DO included DO and biochemical oxygen demand (BOD).

Water quality constituent loads were calculated by multiplying stream inflows by concentrations of the constituents. For dry weather flow conditions, baseflow loads of DO and BOD were calculated assuming a 5 day BOD concentration of 5 mg/L and a DO concentration of 75% of saturation. For wet weather CSO discharges, concentrations of BOD were based on measured values (2001 Monitoring Data, CDM 2001). Comparisons between modeled and measured instream BOD values led to the development of variable BOD concentrations from CSOs during wet weather events. Higher BOD concentrations were assumed for the first half hour of the storm to reflect a “first-flush” effect that has been observed in CSO sampling. For wet weather runoff in the separate sanitary sewer area, event mean concentration (EMC) data for BOD was assigned to various land uses based on literature values from previous studies. EMC data was estimated for each subbasin as a function of the land use distribution in each subbasin. DO values were assumed to be 75% of saturation.

Key instream rate constants for the DO analysis included the BOD decay rate, the reaeration rate and the sediment oxygen demand (SOD) rate. The BOD decay rate is the rate at which carbonaceous BOD is oxidized, consuming stream DO in the process. A variable systemwide decay rate that is a function of the instream BOD concentration was developed, calibrated, and verified. This decay rate is particularly critical during wet weather events, where high instream BOD concentrations are primarily due to CSOs. BOD from CSOs is more easily oxidized than the lower levels of BOD that are found in baseflow or stormwater runoff. However, special (high) reaeration rates were assigned to locations downstream of dams, to account for the reaeration that occurs when water travels over the dam spillway. SOD is an assumed sink of oxygen caused by decomposition of organic matter in stream sediments. The highest SOD values were assigned just upstream of dams, where organic matter would be expected to settle as the streamflow is slowed down by backwater effects.

Another key physical model parameter is water temperature. For processes such as BOD decay, reaeration and SOD, the rates are typically assumed to increase as water temperature increases. In addition, the DO saturation concentration is lower at higher temperatures. For the dry weather and wet weather calibration and verification events, the water temperature values were set as input values in WASP.

Like the DO modeling, the three key input categories for *E. coli* bacteria modeling in WASP are physical stream parameters, water quality constituent loads, and instream rate constants. *E. coli* bacteria were modeled in WASP using the same framework as the BOD/DO model. Advection of *E. coli* bacteria between model segments was the key physical transport process.

Water quality constituent loads were calculated by multiplying stream inflows by constituent concentrations. For dry weather flow conditions, baseflow loads of *E. coli* bacteria were initially calculated assuming a concentration of 150/100 mL, which was representative of the dry weather geometric mean at a number of sampling stations in the study area. For wet weather CSO discharges, a typical concentration of 900,000 cfu/100 mL was initially assigned based on monitoring data. Comparisons between modeled and measured instream *E. coli* bacteria concentrations led to the development of variable *E. coli* bacteria concentrations from CSOs during the wet weather events. The higher concentration of 900,000 cfu/100 mL was assumed for the first half hour of the storm to reflect a first-flush effect. In the separate sanitary sewer areas, a typical stormwater concentration of 3,000 cfu/100 mL was assigned based on literature values.

The key instream rate constant for the *E. coli* bacteria analysis was the first-order die-off. A rate of 1.0 per day was initially assigned and confirmed during the calibration process. This value corresponds to roughly 90% die-off of bacteria over a 48 hour period.

### 3.2.3 Calibration and Verification

Water quality monitoring was conducted in the White River and Fall Creek between September and November 1998 in support of the CSO LTCP development. The monitoring program consisted of wet-weather grab sample collection at 12 sites on the White River, Fall Creek, Pleasant Run, Pogues Run, and Eagle Creek; as well as continuous DO metering at six locations. The first sampled storm event occurred on October 6, 1998 and the second event occurred on October 18, 1998.

Observations from a review of the collected data include the following:

- Fall Creek often experiences a significant drop in DO (minimum concentrations as low as 1 mg/L were observed) at the confluence with the White River during storm events. DO drops also occur in the White River at the Raymond Street and IPL Pool sampling stations.
- The water quality response of the White River and Fall Creek systems appears to be dependent on storm event characteristics such as volume, peak intensity, time of occurrence of peak intensity, and antecedent conditions.
- Significant increases in BOD concentrations occurred in the White River at locations within and downstream of the CSO area during and after rainfall events. The peak BOD concentration observed in the White River was 18 mg/L. Peak BOD concentrations observed at the discharge points of tributaries with CSOs (Fall Creek, Pogues Run, Pleasant Run, Eagle Creek) ranged from 15 to 70 mg/L.

The data clearly indicates that BOD in CSO discharges is a major contributor to the DO drops that can occur in the White River and Fall Creek system during storm events. In addition, DO concentrations are often low between storm events at some locations, such as Fall Creek at Boulevard Place.

The water quality model of the White River and Fall Creek was initially calibrated using two measured events. The first event was a dry weather period followed by a 2.26-inch storm event on October 6, 1998. The second event was a dry weather period followed by a 0.81-inch storm event on October 18. Both storms were sufficiently large to produce combined sewer overflows as well as substantial runoff from separate sanitary sewer areas. The 1998 monitoring and sampling data are presented in Appendix D of the Stream Reach Characterization and Evaluation Report (ICST, 2003).

Additional instream and CSO data was collected during 2001. The data included:

- CSO discharge monitoring for BOD, *E. coli* bacteria and dissolved oxygen
- Continuous instream dissolved oxygen and temperature at five locations
- Time-of-travel measurements for Fall Creek and White River
- Dam reaeration measurements
- Instream phytoplankton measurements

This data was used to further verify the accuracy of the instream model as described in this section. During 2002, the instream model was expanded to include Pogues Run, Pleasant Run and Eagle Creek, and the White River model was extended to Petersburg. At that time, the model was verified for the monitoring data collected in 2001. The model validation used data from storm events that occurred on August 31 and September 7, 2001.

The following sections summarize the calibration and verification of the water quality model. Section 3.2.3.1 provides an overview of the calibration and verification process. Section 3.2.3.2 describes the calibration and verification of the dry weather periods preceding the two selected storm events, and section 3.2.3.3 describes the calibration and verification of the two selected storm events.

#### 3.2.3.1 Calibration and Verification Overview

The overall objective of model calibration and verification is to define values of key model parameters for an acceptable match between the measured data and the model results. The calibrated parameter values should be within the range of typical values presented in literature, unless a reason is established for local values that are atypical from the accepted range.

#### 3.2.3.2 Dry Weather Calibration and Verification

Prior to the evaluation of a storm event, the antecedent dry weather period is simulated. For each pre-event period, the analysis began with a dry weather flow balance. An acceptable flow balance allows for the evaluation of the water quality parameters. The model results provided a reasonable representation of the measured water quality constituent concentrations, as well as providing initial conditions for the storm event modeling. This section documents the dry weather calibration and verification of the hydrology and hydraulics of the receiving stream model, and the dry weather calibration and verification of the water quality models for BOD, DO, and *E. coli* bacteria.

**Hydrology and Hydraulics**

In order to establish the dry weather pre-event conditions for the two calibration events, the physical stream parameters required for the dry weather water quality modeling were developed by running the EXTRAN block of the receiving stream SWMM model under steady flow conditions until steady state conditions were achieved. **Figure 3-2** shows the dry weather pre-event flow conditions for the White River. For the two 2001 events, the streamflows range from 300 cfs just upstream of the Broad Ripple Dam, to 700 cfs at the downstream end of the system (USGS gage at Centerton). The flow balance includes a 115 cfs withdrawal by IWC, which is the reason that the minimum streamflow is located just upstream of the Broad Ripple Dam.

Dry weather pre-event flow conditions for Fall Creek, Pleasant Run, Eagle Creek and Pogues Run are presented in **Figures 3-3** through **Figure 3-6**. The Fall Creek flow balance includes a 38 cfs withdrawal by IWC, which is the reason that the minimum pre-event streamflow is located in the combined sewer area. The pre-event streamflow in Pleasant Run and Pogues Run is very low – virtually zero - compared to the other streams.

### BOD and Dissolved Oxygen

For the BOD and DO simulation, the key processes in achieving a representative model of the stream system were reaeration and SOD. **Figures 3-7** and **3-8** compare the measured and modeled instream DO concentrations on the White River for the pre-event conditions. In both cases, the measured values at all stations were above the instream DO standards of 5 mg/L daily average and 4 mg/L minimum standard. The modeled DO values in all cases are within 1 mg/L of the measured values. Modeled DO values were lowest just upstream of the 16th Street and Chevy dams. These two dams have relatively low flow, which causes low reaeration and relatively high SOD values.

Measured and modeled instream DO concentrations for Fall Creek are presented in **Figures 3-9** and **3-10**. In both cases, the average of the measured values was above the instream DO standards of 5 mg/L daily average and 4 mg/L minimum standard. Modeled DO values were lowest just upstream of the Boulevard dam, due to relatively low reaeration and relatively high SOD values at the dam.

**Figures 3-11** through **Figure 3-16** compare the measured and modeled instream DO concentrations for Pleasant Run, Eagle Creek and Pogues Run. For all cases, the average of the measured values was above the instream standards of 5 mg/L daily average and 4 mg/L minimum standard.

### *E. coli* Bacteria

For the *E. coli* bacteria simulation, historical data was used to validate the model. Key parameters were adjusted such that the modeled instream bacteria concentrations were consistent with the geometric mean of designated dry weather bacteria samples taken in 2000 and 2001 within the study area.

The most critical components of the *E. coli* bacteria modeling were the *E. coli* bacteria loads and the first-order die-off rate. In the absence of detailed instream data, a first-order die-off rate of 1.0 per day was initially assigned and confirmed during the calibration process. Baseflow *E. coli* bacteria concentrations were initially assigned based on historical instream data.

Historical and modeled dry weather *E. coli* bacteria data are compared in **Figures 3-17** through **Figure 3-26**. For the White River, Fall Creek, Pleasant Run, Eagle Creek, and Pogues Run, the modeled *E. coli* bacteria concentrations are similar to the geometric means of the historical dry weather data. In some cases, particularly the White River upstream of Marion County and downstream of the IPL dam, the measured and modeled dry weather *E. coli* bacteria concentrations exceed the daily maximum *E. coli* bacteria standard of 235 cfu/100 mL.

#### 3.2.3.3 Wet Weather Calibration and Verification

Following the model calibration and verification for the two dry pre-event periods, the model was further calibrated and verified for the two 2001 storm events. The following sections document the wet weather calibration and verification of the hydrology and hydraulics of the receiving stream model and the water quality models for BOD, DO, and *E. coli* bacteria.

### Hydrology and Hydraulics

Two key parameters for calibrating and verifying the hydrology and hydraulics model are flow volume and peak flow at gauged locations in the study area. Flow volume calibration and verification allows the model to represent an appropriate amount of combined sewer overflow and runoff discharged to the river. Because over 98% of the study area consists of non-CSO (i.e. sanitary, septic, unsewered) areas, direct surface runoff to the stream system is the major component of wet weather flow volume.

The calibration of flow volume focused on subbasin hydrology parameters in the RUNOFF block of the SWMM model for separate sanitary sewer areas. The most critical RUNOFF parameter is the directly connected impervious area (DCIA). Initial DCIA values were established for various land use types, and initial subbasin DCIA values were assigned based on these values and the subbasin land use distribution. **Figure 3-27** presents calculated and measured flow volumes for the two 2001 wet weather events. As shown in the figure, the calculated flow volumes are within 10% of the measured volumes at most locations for both events. The 10% tolerance value was set as a calibration/verification goal for the study.

Calibration of peak flow also focused primarily on subbasin hydrology parameters in the RUNOFF block of the SWMM model for separate sanitary sewer areas. **Figure 3-28** presents calculated and measured peak flows for the two wet weather events. As shown in the figure, the calculated flow volumes are in most cases within 10% of the measured volumes. Because CSO control measures will be expected to control relatively small events, the results shown in Figure 3-28 are considered acceptable for wet weather hydrology and hydraulics calibration and verification.

Measured and modeled flows at White River and Fall Creek locations are presented in **Figures 3-29** through **Figure 3-38**. The five locations represent the USGS stations on the White River and Fall Creek within the study area. All of the plots reflect model results that are comparable to measured data with respect to flow volume, peak flow, and timing of the peak, further emphasizing the validity of the model's hydrology and hydraulics representation of the study area response to typical rainfall conditions.

### BOD and Dissolved Oxygen

Because BOD and DO simulation factors such as reaeration and SOD were addressed in the dry weather calibration, the key factors in achieving a representative wet weather model simulation of DO in the stream system were BOD loads and the BOD decay rate. BOD loads to the model were calculated as the product of stream inflows and BOD concentrations. For separate sanitary sewer areas, subbasin runoff BOD concentrations ranged between 4.5 mg/L for forests and open areas to 57 mg/L for medium density residential areas. For combined sewer areas, combined sewer overflow BOD concentrations were assigned based on the 2001 CSO discharge monitoring. The assigned concentrations reflected a first-flush effect, with BOD concentrations of 100 mg/L or more during the first 20 minutes of the CSO discharge; 60 mg/L from 20 to 60 minutes; and 50 mg/L or less after the first hour. The DO concentration for discharges from CSO and stormwater was set at 75% of the temperature-specific DO saturation concentration.

The calibrated BOD decay rate represents a range of instream decay rates, depending upon the instream BOD concentration. The applied BOD decay rate increases as the BOD concentration increases.

**Table 3-1** presents a range of instream BOD decay rates as established in model calibration and verification. The table shows the BOD decay rates for corresponding values of 5 day carbonaceous BOD ($CBOD_5$) and ultimate carbonaceous BOD (CBODU). Under dry weather conditions, instream $CBOD_5$ values were approximately 5 mg/L, and the assumed BOD decay rate is 0.10/day. This corresponds to a CBODU concentration of 12.5 mg/L, and an ultimate/5-day ratio of 2.5. Measured peak $CBOD_5$ values from grab samples during the two storm events varied from 20 to 70 mg/L, which would correspond to BOD decay rates from 0.16 to 0.22/day.

**Figure 3-39** compares the measured and modeled minimum instream DO on the White River and its tributaries for the wet weather events. As shown in Figure 3-39, most of the modeled minimum DO values fall within 15% of the measured minimum DO.

**Figures 3-40** through **3-51** compare measured and modeled DO values for the calibration and verification events at specific locations on the White River, Fall Creek, Pleasant Run, and Eagle Creek. The data presented is the DO measured and modeled along the stream system over a 5 day period beginning on the day of the rainfall event.

**Figures 3-52** and **3-53** present the measured and modeled minimum DO values for the calibration and verification events on the White River. As shown in the figures, the measured and modeled DO values are typically within 1 mg/L of each other, and the modeled drops in DO from dry weather to wet weather conditions are consistent with the measured DO drops (typically 1 to 3 mg/L). For both events, the model calculates the minimum DO concentration just upstream of the Chevy dam. The minimum modeled DO for both events drops below the minimum instream DO standard (4 mg/L), but no actual measurements were made at that location to verify the modeled DO drop.

The relationship between the measured and modeled minimum DO concentrations for Fall Creek is presented in **Figures 3-54** and **3-55**. As shown in the figures, the measured and modeled DO values are typically within 1 mg/L of each other, and the modeled drops in DO from dry weather to wet weather conditions are consistent with the measured DO drops. For both events, the model calculates the minimum DO concentration just upstream of the Boulevard dam. The minimum modeled DO for both storm events drops below the minimum instream DO standard (4 mg/L), and these drops were verified by measurements made just upstream of the dam site.

The relationship between the measured and modeled minimum DO concentrations for Pleasant Run, Eagle Creek and Pogues Run are presented in **Figures 3-56** through **3-61**. As shown in the figures, the measured and modeled DO values are typically within 1 mg/L of each other, with the exception of Eagle Creek on the September 7, 2001 storm event. For both events, a significant drop in DO from dry weather to wet weather conditions was not observed in Pleasant Run, Eagle Creek or Pogues Run. This is due to the relatively short wet weather travel time in the tributary streams.

Based on the results, the receiving water quality model provides a realistic representation of DO conditions in the White River and its tributaries during dry weather and wet weather conditions. The model indicates that DO drops up to 4 mg/L can be expected during storm events, resulting in DO concentrations less than the minimum instream DO standard. Additional calibration plots are provided in **Appendix D** of this report.

### *E. coli* Bacteria

Similar to the dry weather conditions, the key factor in achieving a representative wet weather model simulation of *E. coli* bacteria in the White River and its tributaries was an appropriate representation of the *E. coli* bacteria loads. These loads to the model were calculated as the product of stream inflows and *E. coli* bacteria concentrations. For separate sanitary sewer areas, subbasin runoff bacteria concentrations were initially set at 3,000 cfu/100 mL *E. coli* bacteria, based on literature values. For combined sewer areas, *E. coli* bacteria concentrations of 900,000 cfu/100 mL were initially set based on CSO monitoring data. Comparisons between modeled and measured instream *E. coli* bacteria concentrations led to the development of variable *E. coli* bacteria concentrations from CSOs during the wet weather events. The higher concentration of 900,000 cfu/100 mL was assumed for the first half hour of the storm to reflect a first-flush effect.

Because no instream *E. coli* bacteria data was collected during the wet weather events, the *E. coli* bacteria loads were calibrated to historical wet weather bacteria sampling data. The selected stormwater and CSO discharge concentrations were consistent with the historical maximum grab sample *E. coli* bacteria concentrations collected at 17 historical monitoring stations, and with instream *E. coli* bacteria data collected by the Marion County Health Department and the Department of Public Works in 2000 and 2001. Headwater *E. coli* bacteria concentrations on the White River and Fall Creek were based on historical sampling data. For the White River upstream of Marion County, out-of-county stormwater *E. coli* bacteria was initially set at 1,000 cfu/100 mL and was confirmed during the calibration process. For the headwaters of Fall Creek, the historical data indicated a stormwater concentration of 2,000 cfu/100 mL.

**Figures 3-62** and **3-63** compare the historical and simulated bacteria values based on the model results for the August 31, 2001 and the September 7, 2001 storm events. At the monitoring stations, *E. coli* bacteria values are presented for the geometric mean and the 95% level of all grab sample measurements. The model was validated assuming that the modeled *E. coli* bacteria concentration should be consistent with the maximum measured grab sample values. The figure illustrates that the model results follow the same patterns of *E. coli* bacteria concentrations that have been measured historically in the study area. On the White River, both the model and historical data show increases in bacteria levels just below the confluence with Fall Creek. **Figures 3-64** and **3-65** present the same comparison for Fall Creek. Validation plots are presented for Pleasant Run, Eagle Creek and Pogues Run in **Figures 3-66** through **3-71**, respectively. The *E. coli* bacteria concentrations at all locations downstream of CSO discharges consistently exceed the daily maximum *E. coli* bacteria standard of 235 cfu/100 mL.

Based on the results, the receiving water quality model provides a realistic representation of *E. coli* bacteria concentrations in the White River and its tributaries during dry weather and wet weather conditions. The model indicates that *E. coli* bacteria concentrations above 235 cfu/100 mL can be expected during storm events, resulting in exceedances of the *E. coli* bacteria daily maximum standard. Additional calibration plots are provided in **Appendix D** of this report.

## 3.3 *E. coli* Bacteria Load Model

This section describes the development, validation and baseline findings of the *E. coli* bacteria load model used to evaluate the performance of all major Indianapolis watersheds against (1) the monthly geometric mean standard of 125 cfu/100 mL, (2) the reference criteria of no more than 10% of samples greater than 235 cfu/100 mL, (3) the reference criteria of no samples greater than 10,000 cfu/100 mL, and (4) additional *E. coli* bacteria levels of 2000 cfu/100 mL and 5000 cfu/100 mL. The reference criteria are documented in IDEM's 303(d) Listing Methodology (IDEM, 2002).

### 3.3.1 Introduction

*E. coli* bacteria load models for the following watersheds were developed and validated to the existing instream *E. coli* bacteria data. These models simulate the daily instream *E. coli* bacteria counts for each stream segment based on the characterized *E. coli* bacteria loads from the sources described in Section 3.3.2. **Figures 3-72** through **3-76** present the stream segments for each model developed. These segments are listed below:

- White River North – 96th Street to I-65
- White River CSO Area – I-65 to I-465
- White River South – I-465 to Waverly
- Fall Creek Upstream of the CSO Area – Geist to Keystone
- Fall Creek CSO Area – Keystone to White River
- Pleasant Run Upstream of the CSO Area – 30th Street to 9th Street
- Pleasant Run CSO Area – 9th Street to White River
- Pogues Run CSO Area – I-70 to New York
- Eagle Creek CSO Area – Michigan to White River

The White River, Fall Creek and Pleasant Run *E. coli* bacteria load models were developed to support the development of TMDLs for each watershed in 2003. For the Systemwide Plan analysis, the White River CSO Area, Fall Creek CSO Area, and Pleasant Run CSO Area models were used to predict the *E. coli* bacteria concentrations in CSO areas. The Pogues Run CSO Area and Eagle Creek CSO Area *E. coli* bacteria load models were developed to support the CSO LTCP Systemwide Plan analysis in 2004.

### 3.3.2 Development

The long-term *E. coli* bacteria load models were developed to simulate the impact of both dry and wet weather sources to the White River and its tributaries. The model simulates wet weather *E. coli* bacteria sources including CSOs and urban and residential nonpoint sources. Additional work was performed to define the sources of dry weather *E. coli* bacteria and the components of urban and residential nonpoint source wet weather contaminants. *E. coli* bacteria for the watersheds was characterized from the following sources:

- Septic systems
- Unpermitted connections to storm drains
- Advanced Wastewater Treatment (AWT) plants
- Wildlife/natural
- Stormwater runoff
- Combined sewer overflows
- Upstream sources

The source assessment evaluated the type, magnitude, timing, and location of pollutant loading to the impaired water bodies for *E. coli* bacteria. The relative rankings of the pollutant contribution for each parameter were established based on available source data. Additional source information can be found in the White River TMDL Report (IDEM, 2003), Fall Creek TMDL Report (IDEM, 2003) and the Pleasant Run TMDL Report (IDEM, 2003).

Each dry weather source is represented by a constant *E. coli* bacteria load. Dry weather sources are failing septics, wildlife and natural background, unpermitted storm drain connections and upstream out-of-county sources.

*E. coli* bacteria loads for stormwater runoff and CSO discharges are based on the city's separate sanitary sewer area water quality model for stormwater (SWMM/RUNOFF), and the collection system hydraulic model (NetSTORM) for CSO discharges during wet weather. The results of the city's models are the input to the *E. coli* bacteria load model, so that the *E. coli* bacteria load model includes the loads for both dry and wet weather sources. **Table 3-2** summarizes the daily *E. coli* bacteria loadings from failed septics, unpermitted storm drain connections, wildlife, stormwater, and CSO for each watershed.

A ten year period of time (October 1991 through September 2001) was simulated with the models to predict the *E. coli* bacteria loads to the stream system on a daily basis. Data on stream flow was used to predict the resultant instream *E. coli* bacteria concentration for each day for the ten year period.
Daily flow data for the major stream segments was obtained from the USGS for the period of October 1, 1991 through September 30, 2001. This flow data was used in the daily *E. coli* bacteria model to evaluate the resulting *E. coli* bacteria concentration from the daily loads.

### 3.3.3 Calibration

Model calibration consisted of comparisons of the geometric mean, percent of samples greater than 235 cfu/100 mL, and the number of samples over 10,000 cfu/100 mL per year of sampling. *E. coli* bacteria sampling data was collected between 2000 and 2002 for all watersheds. These comparisons were performed for both dry weather and wet weather data. The calibration of the model for *E. coli* bacteria included quality checks of the USGS daily flow data, adjustment for *E. coli* bacteria contributions from wildlife and stormwater for all reaches, and Pleasant Run failed septic systems.

**Table 3-3** contains a summary of the observed and modeled geometric mean, percent of samples greater than 235 cfu/100 mL, and the number of samples over 10,000 cfu/100 mL per year for all watersheds modeled from October 1991 through September 2001. The model calibration is considered to be within the limitations of the *E. coli* bacteria sampling data and is appropriate for water quality planning purposes. **Table 3-4** presents a sample page from the daily *E. coli* bacteria model for the White River CSO Area. **Figure 3-77** presents the predicted instream *E. coli* bacteria counts for April 1, 1997 to October 31, 1997 for the White River CSO Area segment. The results of the *E. coli* bacteria load models for water quality planning purposes can be found in Section 4.

# 4.0 Model Results

This section presents the hydraulic and water quality modeling results for the 2004 Revised CSO LTCP.

## 4.1 NetSTORM

This section describes the results of the NetSTORM modeling analysis.

### 4.1.1 Existing Conditions

**Table 4-1** presents the systemwide NetSTORM results for existing conditions during the 1950-2003 precipitation record. The systemwide percent capture ranges from 62 to 68 percent. **Tables 4-2** through **4-6** present the NetSTORM results by CSO for the Fall Creek, Pleasant Run, Pogues Run, Central Sub-Network, and System Relief reaches of the Indianapolis system. Eagle Creek is part of the Central Sub-Network. The NetSTORM model is considered to be more suitable for generating systemwide or reach-wide CSO statistics, as opposed to individual CSO statistics.

### 4.1.2 Baseline Findings

To support CSO alternative analysis and facility sizing for the Indianapolis CSO LTCP, the Indianapolis NetSTORM model was updated to include early action projects (EAP) and supplemental projects. These projects represent the baseline condition for the modeling analysis. The Draft Memorandum Early Action Projects for Modeling (ICST, February 12, 2004), and Draft Memorandum Control Technology Rationale (ICST, February 17, 2004) detail proposed EAP and supplemental projects to be included as the baseline condition for the system.

For purposes of NetSTORM modeling, projects can be divided into the following categories: inflatable dams, sewer separation, sewer rehabilitation, storage facilities, and conveyance facilities. Conceptual approaches for each category are described below.

#### Inflatable Dams

There are nine inflatable dam and sluice gate projects. Operational data has been recovered for four of the inflatable dams from design memorandums. Each dam is assumed to store CSO flows up to the volume documented in the in-system storage analysis in the CSO Operational Plan (CSOOP) unless revised storage information from the design memoranda is available. In the case that a CSO was not analyzed in the 1995 CSOOP and no additional data is available, the average storage volume for the CSO outfall pipe size was assumed. Available storage volumes have been refined for four dams from additional data found in the 2004 reports produced by Triad Engineering Corporation (TEC) and MS Consultants (MSC).

Wet weather flow that arrives at the regulator will be stored up to the available storage volume. After available storage has been exhausted, excess wet weather flow will result in an overflow into the proposed CSO facilities to meet the desired level of control.

The NetSTORM representation assumes that stored CSO can be dewatered to existing interceptors in one day. Due to the relatively low dewatering rates, the representation also assumes that stored flows can be dewatered to the existing interceptors if there is available conveyance capacity.

#### Sewer Separation

Sewer separation is modeled in NetSTORM by reducing the CSO basin’s C-value to 5.0. This approach assumes that 5% of the rainfall that falls over the separated CSO basin still enters the collection system after separation is completed. This is a conservative assumption.

### Sewer Rehabilitation
Sewer rehabilitation is modeled in NetSTORM by assuming that all wet weather flow that previously resulted in overflow will be eliminated through reducing wet weather flow to the existing sewer system. Of all the EAPs, only CSO 103 is slated for sewer rehabilitation. According to the 2002 CSO 103 System Investigation by GRW, Inc., CSO elimination will consist of cured in-place pipe rehabilitation, and reduction of inflow through replacement of manhole covers. Since the replacement of manhole covers is not expected to remove all inflow and infiltration (I/I), it will be assumed that 50% of wet weather flow will be removed from the collection system, with the remaining 50% conveyed to the downstream Fall Creek system.

### Storage Facilities
Storage facilities are modeled in NetSTORM such that stored CSO can be dewatered in 0.5 to 2 days depending on facility and downstream interceptor system capacity. The representation assumes that stored flows can be dewatered after the storm event. Due to the relatively low dewatering rates, the representation may be modified such that stored CSO flow is held until a certain number of hours after the storm event has passed. This modification would be made if the premature release of stored flow is contributing to overflows in the downstream system.

### Conveyance Facilities
Conveyance facilities may be identified as relief sewers, CSO consolidation sewers, or cut-off sewers, depending on the project name. Conveyance facilities are modeled in NetSTORM by conservatively assuming that the theoretical capacity of the pipe is the ultimate capacity. The model does not consider additional flows that may be conveyed through the interceptor under surcharged conditions. Conveyance facilities in NetSTORM are modeled with incidental storage available in the tributary sewer system.

### Specific Facility NetSTORM Representation
All EAP information incorporated into the NetSTORM model is summarized in **Table 4-7.**

**Table 4-7**
**NetSTORM Representation of Early Action Projects**

| Watershed | CSO # | EAP Type | Conveyance Capacity (MGD) | Storage Volume (MG) | Information Source |
|---|---|---|---|---|---|
| Fall Creek | 53 | Inflatable Dam | N/A | 0.070 | 1995 CSOOP |
| Fall Creek | 58 | Sluice Gate | N/A | 0.075 | 1995 CSOOP |
| Fall Creek | 63 | Inflatable Dam | N/A | 1.222 | 1995 CSOOP |
| Fall Creek | 63A | Inflatable Dam | N//A | 1.250 | 1995 CSOOP |
| Fall Creek | 65 | Inflatable Dam | NA | 2.170 | 1995 CSOOP |
| Fall Creek | 103 | I/I Removal & Rehab | N/A | N/A | 2002 GRW (Facilities Plan) |
| Pleasant Run | 80 | Inflatable Dam | N/A | 0.03 | 2004 TEC |
| Pleasant Run | 84 | Inflatable Dam | N/A | 0.35 | 2004 TEC |
| Pogues Run | 101 | Inflatable Dam | N/A | 0.4 | 2004 MSC |
| Pogues Run | 36, 95, 96, 97, 98, 99, 100, | Spades Park Storage Tank | N/A | 4.0 | 2001 LTCP |
| Pogues Run | 34, 35, 136 | Consolidation Sewer | 98 (U/S) 457 (D/S) | N/A | 2003 Design Memo by Clark Dietz |
| Pogues Run | A138, 137, 133, 152, 129, 125, 138, 128, 153, 115 | Barrel Conversion for Storage and Conveyance | 715 | 10 | 2001 LTCP (storage volume) 2004 VS Engineering (conveyance capacity) |
| Eagle Creek | 33, 223, 32, 11, 145 | Relief Interceptor | 105 | 0.5 | 2001 LTCP (12 OF/yr) |
| Lick Creek | 235 | Sewer Separation | N/A | N/A | 2004 ICST |
| State Ditch | 217, 218 | Sewer Separation | N/A | N/A | 2001 LTCP |
| Lick Creek | 235 | Sewer Separation | N/A | N/A | 2004 ICST |
| State Ditch | 217, 218 | Sewer Separation | N/A | N/A | 2001 LTCP |
| Upper WR | 155, 156, 205 | Riviera Storage Tank | N/A | EAP = 1.0 | 2004 ICST |
| Lower WR | 37, 38, 39 | Storage Tank | N/A | 3.0 | 2001 LTCP |
| Lower WR | 45 | Vortex | 20 | N/A | 1997 Project Description |
| Lower WR | 117 | Interplant Connection | 344 | 6.0 | 2004 Interplant Connection Facilities Plan |

**Table 4-7 (Continued)**
**NetSTORM Representation of Early Action Projects**

| Watershed | CSO # | EAP Type | Conveyance Capacity (MGD) | Storage Volume (MG) | Information Source |
|---|---|---|---|---|---|
| Lower WR | 118 | Inflatable Dam | N/A | 0.12 | 2004 TEC |
| Lower WR | 275 | Sewer Separation | N/A | N/A | 2004 ICST |
| Belmont AWT | 008 | AWT Upgrades | 300 | 34 | 2004 ICST |
| Southport AWT | | AWT Upgrades | 300 | 25 | 2004 ICST |

**Table 4-8** summarizes supplemental projects that are also part of the baseline condition. The Riviera and Spades Park Storage Tanks and the Eagle Creek Relief Interceptor will be sized for each level of CSO control as supplemental projects.

**Table 4-8**
**NetSTORM Representation of Supplemental Projects**

| Watershed | CSO # | Project Type | Conveyance Capacity (MGD) | Storage Volume (MG) | Information Source |
|---|---|---|---|---|---|
| Bean Creek | 17 | Separation | N/A | N/A | 2004 ICST |
| Pogues Run | 36, 95, 96, 97, 98, 99, 100, | Spades Park Storage Tank | Varies per Level of Control | Varies per Level of Control | 2001 LTCP |
| Pogues Run | 143 | Sewer Separation | N/A | N/A | 2004 ICST |
| Eagle Creek | N/A | Belmont North & West Cutoff | 164 | 0.5 | 2004 CDM |
| Eagle Creek | 33, 223, 32, 11, 145 | Relief Interceptor | Varies per Level of Control | Varies per Level of Control | 2001 LTCP (12 OF/yr) |
| Upper WR | 155, 156, 205 | Riviera Storage Tank | Varies per Level of Control | Varies per Level of Control | 2004 ICST Settling/Disinfection with a minimum residence time of 30 minutes is applied to attain higher levels of control. |
| Lower WR | 46 | Separation | N/A | N/A | 2004 ICST |

The EAP and supplemental projects representing the baseline condition are expected to increase the systemwide percent capture to 77%.

**Appendix E** contains all hydraulic and water quality modeling results for the baseline condition. The results include the reduction in average annual CSO volume, BOD loads, and *E. coli* bacteria loads.

### 4.1.3 Watershed Evaluation

The NetSTORM model was applied to evaluate alternatives for the Pleasant Run and Fall Creek Watershed Alternative Evaluations. For each watershed, numerous alternatives comprised of storage, conveyance, treatment, and separation technologies were evaluated. The Pleasant Run Watershed Evaluation was submitted to U.S. EPA and IDEM on September 8, 2003. The Fall Creek Watershed Evaluation was submitted on November 7, 2003. Specific model results include facility sizing and the reduction in average annual CSO volume, BOD loads, and *E. coli* bacteria loads.

### 4.1.4 Systemwide Plan Analysis

The NetSTORM model was applied to evaluate Systemwide Plans 1 and 2, which are described in the Control Technology Rationale Memorandum (ICST, February 17, 2004). Both plans consist of storage and conveyance facilities in all watersheds. In Systemwide Plan 1, all facilities convey captured CSO to the AWT Plants, whereas in Systemwide Plan 2, the Fall Creek and Pogues Run facilities convey captured CSO to remote treatment facilities that discharge to the White River. In addition to these two plans, systemwide sewer separation was also considered but not explicitly modeled in NetSTORM. **Figures 4-1** and **4-2** present schematics for the two plans.

**Tables 4-9** and **4-10** present the facility sizes for Systemwide Plans 1 and 2, respectively. The facility sizes for Systemwide Plan 1, at the 4 overflow/yr level of control, were confirmed with SWMM continuous simulations. Please refer to the table endnotes for additional information regarding the facility sizes. **Appendix E** contains all hydraulic and water quality modeling results used to support Systemwide Plans 1 and 2.

## 4.2 WASP

This section describes the results of the Water Quality Analysis Simulation Program (WASP) modeling analysis.

### 4.2.1 Existing Conditions

WASP simulations were performed for all major stream segments to provide the existing dissolved oxygen (DO) and *E. coli* bacteria conditions. During storm events, all stream segments are expected to exceed the *E. coli* bacteria daily maximum standard of 235 cfu/100 mL, while Fall Creek and the White River are expected to exceed the minimum dissolved oxygen standard of 4.0 mg/L.

### 4.2.2 Baseline Findings

The baseline conditions, or the implementation of early action and supplemental projects, was not simulated in WASP as the baseline condition on its own is not expected to attain compliance with the minimum DO standard of 4.0 mg/L on Fall Creek or the White River, or the *E. coli* bacteria daily maximum standard of 235 cfu/100 mL on all streams. This was confirmed by simulating the effects of a 12 overflows/year level of control in WASP.

### 4.2.3 Watershed Evaluation

The WASP model was applied to evaluate alternatives for the Pleasant Run and Fall Creek Watershed Alternative Evaluations. For each watershed, numerous alternatives comprised of storage, conveyance, treatment, and separation technologies were evaluated. The Pleasant Run Watershed Evaluation was submitted to U.S. EPA and IDEM on September 8, 2003. The Fall Creek Watershed Evaluation was submitted on November 7, 2003. Specific model results include the single event DO and *E. coli* bacteria performance for various evaluation storms.

### 4.2.4 Systemwide Plan Analysis

The WASP model was applied to evaluate Systemwide Plans 1 and 2. **Appendix E** contains all the hydraulic and water quality modeling results used to support Systemwide Plans 1 and 2. The modeling analysis for Systemwide Plans 1 and 2 also incorporated the expected water quality benefits of stream improvements that are not directly related to CSO controls. These additional measures are classified as "watershed improvements." The objective of the analysis is to evaluate the cost-effective water quality benefit of the watershed improvements, compared with achieving the same benefit by selecting a higher level of CSO control.

Watershed improvements for the White River and all tributary streams were analyzed in the 2001 LTCP and the 2003 Watershed Alternative Evaluations to evaluate compliance with the instantaneous minimum DO standard of 4.0 mg/L. It should be noted that the DO evaluations were only performed on Fall Creek.

**Table 4-11** summarizes the watershed improvement projects that were identified in prior versions of the LTCP or alternative analyses. These projects were carried forward to support the Systemwide Plan Analyses. For the single event DO modeling, the removal of the Boulevard Dam and temporary aeration were analyzed to attain compliance with the minimum DO standard of 4.0 mg/L on Fall Creek at the levels of control of 12 overflows/year and 6 overflows/year. Although the combination of the Stout Dam modification, Chevy Dam permanent aeration and temporary aeration are believed to attain compliance with the minimum DO standard of 4.0 mg/L on the White River at the 12 overflows/year level of control, no specific water quality modeling analysis was performed.

Additional projects that may be classified as "watershed improvements", and do not have an assumed water quality impact on the White River and its tributaries, include: the Basin Master Plan, the Watershed Team, additional street sweeping, public education, pretreatment improvements, the raised dam at Geist, and the Pogues Run Channel Improvements.

## 4.3 *E. coli* Bacteria Load Model

This section describes the results of the *E. coli* bacteria load modeling analysis.

### 4.3.1 Existing Conditions

The *E. coli* bacterial load model was applied for all major stream segments to provide the existing *E. coli* bacteria conditions. **Appendix E** contains all hydraulic and water quality modeling results used to support Systemwide Plans 1 and 2. Table 3-3 contains specific *E. coli* bacteria parameters under existing conditions.

### 4.3.2 Baseline Findings

The EAP and supplemental projects are expected to provide a small improvement in *E. coli* bacteria concentrations in the White River and its tributaries. Appendix E contains all hydraulic and water quality modeling results, including the baseline condition results. The results include the *E. coli* bacteria performance against the monthly geometric mean standard of 125 cfu/100 mL; the reference criteria of no more than 10% of samples above 235 cfu/100 mL; the reference criteria of no samples over 10,000 cfu/100 mL; and additional bacteria levels of 2000 cfu/100 mL and 5000 cfu/100 mL.

### 4.3.3 Watershed Evaluation

The *E. coli* bacteria load model was applied to evaluate alternatives for the Pleasant Run and Fall Creek Watershed Alternative Evaluations. For each watershed, numerous alternatives comprised of storage, conveyance, treatment, and separation technologies were evaluated. The Pleasant Run Watershed Evaluation was submitted to U.S. EPA and IDEM on September 8, 2003. The Fall Creek Watershed Evaluation was submitted on November 7, 2003.The results include the *E. coli* bacteria performance against the monthly geometric mean standard of 125 cfu/100 mL; the reference criteria of no more than 10% of samples above 235 cfu/100 mL; the reference criteria of no samples over 10,000 cfu/100 mL; and additional bacteria levels of 2000 cfu/100 mL and 5000 cfu/100 mL.

### 4.3.4 Systemwide Plan Analysis

The *E. coli* bacteria load model was applied for all CSO stream segments to evaluate Systemwide Plans 1 and 2. For example, the White River CSO Area *E. coli* bacteria load model was applied to simulate the *E. coli* bacteria performance for the White River. Appendix E contains all hydraulic and water quality modeling results used to support Systemwide Plans 1 and 2. The modeling analysis for Systemwide Plans 1 and 2 also incorporated the expected water quality benefits of stream improvements that are not directly related to CSO controls. These additional measures are classified as “watershed improvements.” The objective of the analysis is to evaluate the cost-effective water quality benefit of the watershed improvements, compared with achieving the same benefit by selecting a higher level of CSO control.

Watershed improvements for the White River and all tributary streams were analyzed in the 2001 LTCP and the 2003 Watershed Alternative Evaluations to evaluate compliance with the *E. coli* bacteria daily maximum standard of 235 cfu/100 mL, and the additional *E. coli* bacteria levels of 2000, 5000, and 10,000 cfu/100 mL.

Table 4-11 summarizes the watershed improvement projects that were identified in prior versions of the LTCP or alternative analyses. These projects were carried forward to support the Systemwide Plan Analysis. For the *E. coli* bacteria load modeling, the following watershed improvements were incorporated: Failing septic system removal, unpermitted connection removal, and stormwater best management practices (BMP) and capital improvement projects (CIP). The analysis also assumed that the White River will be brought into compliance with *E. coli* bacteria standards upstream of Marion County. Specific model assumptions are defined below:

- Failing septic system removal assumed that the *E. coli* bacteria load allocated to septic systems in all Septic Tank Elimination Program priority areas has been removed. The septic system removal is a combination of the existing Septic Tank Elimination Program, and the Accelerated Septic Removal discussed in the 2001 LTCP.
- Unpermitted connection removal assumes that the *E. coli* bacteria load allocated to unpermitted connections from the sanitary system to the stormwater collection system is removed.
- Stormwater BMPs and CIPs are assumed to reduce the *E. coli* bacteria load allocated to stormwater by 10%. The Stormwater Master Plan is included in this load reduction.
- *E. coli* bacteria compliance upstream of Marion County assumes that the White River is in compliance with the *E. coli* bacteria monthly geometric mean standard of 125 cfu/100 mL.

Additional projects that may be classified as “watershed improvements”, and do not have an assumed water quality impact on the White River and its tributaries, include the Basin Master Plan, the Watershed Team, additional street sweeping, public education, and the pretreatment improvements.

As documented in Appendix E, the *E. coli* bacteria impacts of the watershed improvements are more significant than CSO control for some of the *E. coli* bacteria parameters, especially the predicted number of days per year above the daily maximum standard of 235 cfu/100 mL.

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CDM, 2003, 2001 Monitoring Data

CDM, 2003, Fall Creek Total Maximum Daily Load Report.

CDM, 2003, Pleasant Run and Bean Creek Total Maximum Daily Load Report.

CDM, 2003, White River Total Maximum Daily Load Report.

CDM, 2004, South Marion County Regional Interceptor Model Expansion Report.

CDM, 2004, Belmont North Interceptor Model Expansion Report.

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## List of Acronyms

| | |
|---|---|
| AWT | Advanced Wastewater Treatment |
| BMP | Best Management Practices |
| BN | Belmont North |
| BOD | Biochemical Oxygen Demand |
| $CBOD_5$ | 5-Day Carbonaceous BOD |
| CBODU | Ultimate Carbonaceous BOD |
| CIP | Capital Improvement Projects |
| CSS | Combined Sewer System |
| CSO | Combined Sewer Overflow |
| DCIA | Directly Connected Impervious Area |
| DMR | Discharge Monitoring Report |
| DO | Dissolved Oxygen |
| EAP | Early Action Projects |
| HGL | Hydraulic Grade Line |
| IDEM | Indiana Department of Environmental Management |
| I/I | Infiltration and inflow |
| LTCP | Long-Term Control Plan |
| MSC | MS Consultants |
| NetSTORM | Networked Storage Treatment Overflow and Runoff Model |
| TMDL | Total Maximum Daily Load |
| SAWTP | Southport Advanced Wastewater Treatment Plant |
| SMCRI | South Marion County Regional Interceptor |
| SWMM | Storm Water Management Model |
| STORM | Storage Treatment Overflow and Runoff Model |
| TEC | Triad Engineering Corporation |
| U.S. EPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| WASP | Water Quality Analysis Simulation Program |
| WQ | Water Quality |